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IDEAS & INNOVATIONS

Soil carbon sequestration potential in the Hudson Valley, New York—A pilot study utilizing COMET-VR

Cynthia Rosenzweig, Sarah Bartges, Alison Powell, Jake Garcia, Peter Neofotis, Judith LaBelle, Joan Snyder, Angela Yin Yee Kong, and Daniel Hillel

Mitigation of greenhouse gas (GHG) emissions and the reduction of negative impacts to the environment are pertinent to long-term agricultural sustainability (Lal et al. 1999). In 2007, the agricultural sector was responsible for 6% of the total GHG emissions in the United States (413 Tg carbon dioxide equivalents [CO_2e] [455 million tn CO_2e]) (USEPA 2009). The New York State Energy Research and Development Authority reports that GHG emissions for the State of New York totaled 270 Tg CO_2e (298 million tn CO_2e) in 2005, which represented 3.8% of total GHG emissions in the United States (NYSERDA 2009). There is a paucity of recent estimates for GHG emissions from the agricultural region of New York State. However, it can be expected that the percent contribution of agriculture to total GHG emissions from the State of New York is on the same order of magnitude or slightly lower than that for the nation (≤6%).

Certain management practices can reduce GHG emissions from agricultural lands by sequestering carbon (C) in the soil. Methods of agricultural C sequestration include, but are not limited to, conservation tillage and rotational grazing. Conservation tillage refers to a tillage system in which at least 30% of crop residue cover is left on the fields after harvest (Blevins et al. 1977). This protects the soil against erosion and increases the soil C content (Kern and Johnson 1993). No-till management, a variant of conservation tillage, leaves the soil undisturbed from harvest to planting, except for nutrient injection as well as the application of pesticides (Uri 1999). Rotational grazing management usually refers to the division of pastureland into individual grazing units where herds are alternately grazed throughout the season. This practice keeps pastures in a vegetative state, improves grass quality, and reduces the total amount of CO_2 released into the atmosphere by enhancing the soil's C storage capacity (Kimble et al. 2002). In order to encourage farmers to adopt such practices, C credit programs have been established for farmers to sell C credits to other parties wishing to reduce their GHG emissions. Like estimates of C sequestration, agricultural C trading has mainly been conducted for the major cash crops of the Midwest. Carbon trading programs do not exist, however, in regions like New York State's Hudson Valley that are characterized by small-scale and diversified agriculture (Bricklemyer et al. 2007).

Cynthia Rosenzweig and **Daniel Hillel** are senior research scientists, **Peter Neofotis** is a research assistant, and **Angela Yin Yee Kong** is a NASA postdoctoral fellow with the Center for Climate Systems Research at the NASA-Goddard Institute for Space Studies, New York, New York. At the time of this study, **Sarah Bartges** and **Alison Powell** were students in the Department of Environmental Science at Barnard University, New York, New York, and **Jake Garcia** was a graduate student in the Department of Geography, Hunter College, City University of New York, New York, New York. **Judith LaBelle** is the President of and **Joan Snyder** is a Fellow at the Glynwood Center, Cold Spring, New York.

The Hudson Valley agricultural region flanks the Hudson River, which flows from north to south through eastern New York State and is comprised of 10 counties: Albany, Columbia, Dutchess, Greene, Orange, Putnam, Rensselaer, Rockland, Ulster, and Westchester. This region was historically considered the breadbasket of New York State and supported an abundance of fruit, dairy, and vegetable farms. Recently, the region has seen a transition from producing food crops to more profitable ventures such as greenhouses, horses, and hay (J.E. Daly, personal communication). Farmers of smaller, more diverse farms like those within the Hudson Valley have limited options for participation in C trading because most estimates of C sequestration have been calculated for large-scale agriculture. COMET-VR (Voluntary Reporting of Greenhouse Gases-Carbon Management Evaluation Tool) is based on the biogeochemical model, CENTURY (Parton et al. 1987), and is an ideal decision support tool for small-scale farmers, land managers, soil scientists, and other agricultural stakeholders to calculate rates of C sequestration associated with management practices and to assess monetary C trading potential (Paustian et al. 2009).

Understanding the distribution and dynamics of soil C at the regional level is an important step in quantifying regional and global C balances and assessing responses of terrestrial ecosystems to land use change (Paustian et al. 1997). This research aimed to (1) estimate the C sequestration potential of the Hudson Valley agricultural region using the COMET-VR tool and (2) provide New York State scientists and policymakers with the information to begin creating a framework for a C credit program that is also relevant to similar small-scale, diverse farming regions.

METHODS

Geographical Information Systems Analysis of Hudson Valley Agriculture. To begin calculating the soil C sequestration potential of the Hudson Valley, data on farms in the region were coupled with Geographical Information Systems (GIS) mapping technology to identify and locate centers of agricultural activity, as well as to determine the prevalent types of farming and dominant crops in the Hudson Valley region. Data on the size and type of agricultural lands (e.g., land managed for crops, orchards, vineyards, poultry farms, nurseries, and pasture) in the Hudson Valley were derived from Real Property data from the New York State Office of Real Property Services (http://www.orps.state.ny.us/). Using a buffering operation in GIS, the size of each land parcel under agricultural management was represented on a map by creating a circle around the parcel point (centroid) that was equivalent in size to the land area of each agricultural parcel. Land use (figure 1) and agricultural parcel (figure 2) maps were created for the 10 counties in the Hudson Valley.

Calculating Total Carbon Sequestration Potential. To assess the C sequestration potential for the agricultural region of the Hudson Valley, COMET-VR was run to generate the CO_2 emission potential per area of agriculture in the Hudson Valley. COMET-VR provides an interface to the Carbon Sequestration Rural Appraisal

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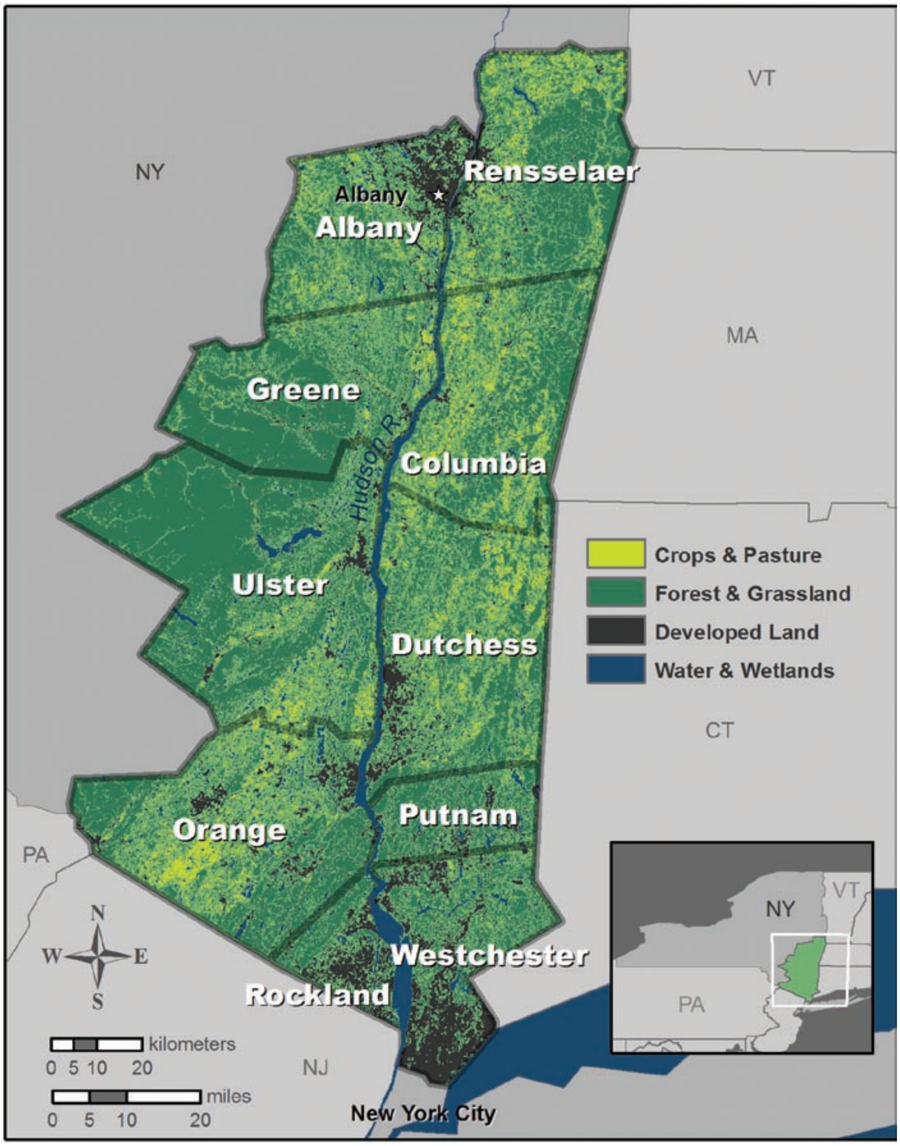
Figure 1

Distribution of land use in the Hudson Valley, New York (2001). Data source: United States Department of Agriculture, Service Center Agencies.



database, which contains land use data and calculates the annual C flux in real time, using a dynamic CENTURY model simulation (http://www.cometvr.colostate.edu). Results from COMET-VR simulations can be presented as 10-year averages of soil C sequestration or CO_2 emissions. We chose to simulate CO_2 emissions, which can be proxies for soil C sequestration, to present the potential for GHG mitigation. Data on the magnitude of the land area devoted to agriculture (e.g., for vegetables, grain/hay crops, and pasture), the diversity and quantity of crops harvested, and the agricultural practices employed (e.g., conservation methods) within each Hudson Valley county were compiled from the National Agricultural Statistics Service, which provides detailed information on agriculture in New York State (via Census of Agriculture). Land use history of the agricultural parcels within the Hudson Valley from the 1800s until 2007 was also compiled. These data, along with data from GIS analysis of Soil Survey Geographic database (SSURGO) and parcel data, provided the input variables needed to run the COMET-VR tool for three management scenarios:

1. Farmers continue their conventional farming practices (Current methods).
2. Farmers convert all cropped land to grass/legume pasture managed under the guidelines of the Conservation Reserve Program (CRP), which began in 1986 to support farmers converting highly erodible and environmentally sensitive land from crop production to perennial grasses or trees (Lal et al. 1999).
3. Farmers convert all cropped land from conventional tillage to no-till and/or rotational grazing (Improved practices).

Soil C sequestration estimates for each county were then summed to calculate the total C sequestration potential for Hudson Valley (in terms of CO_2 emissions) over a 10-year projection.

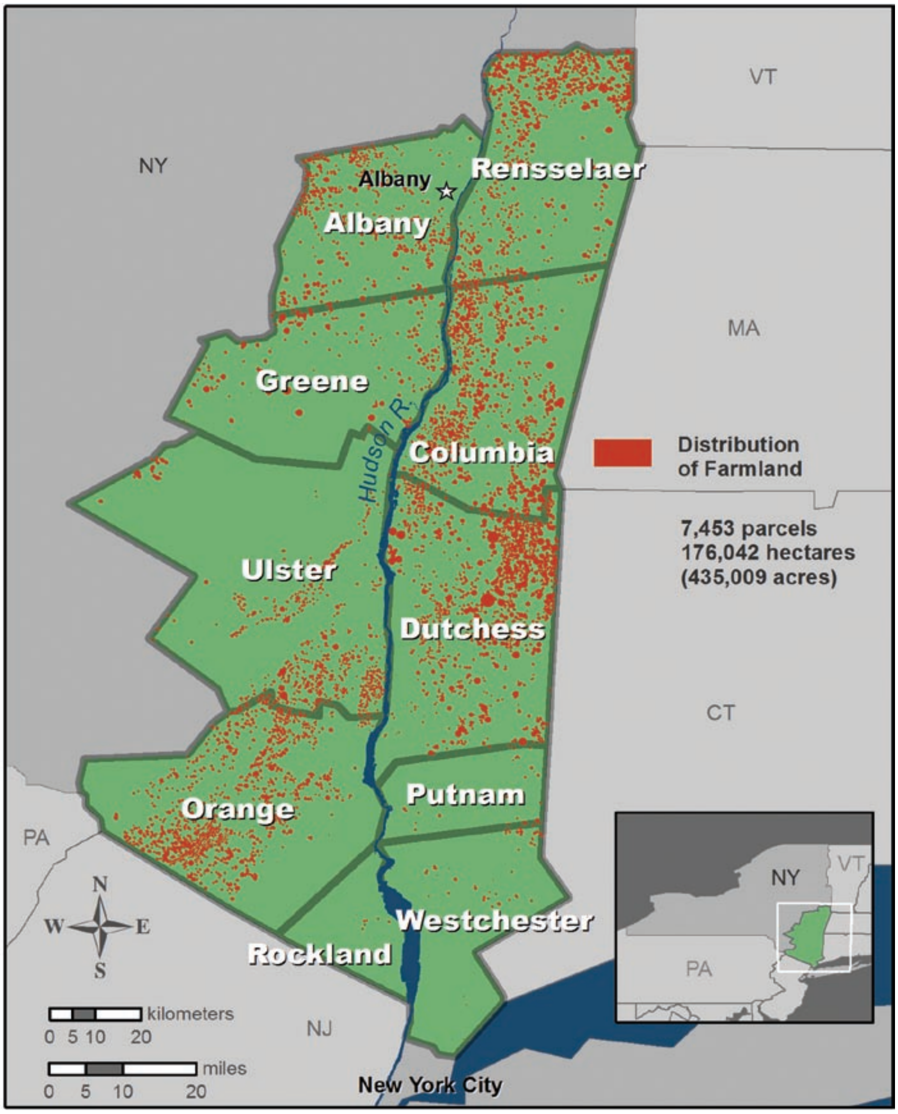
RESULTS AND DISCUSSION

GIS Analysis of Hudson Valley Farms. Of the estimated 176,042 ha (435,009 ac) of total agricultural land in the Hudson Valley, the amount of land devoted to agriculture was different among the 10 counties (figure 3). Over 24% of the agricultural lands in the Hudson Valley are located in Dutchess county, where 42,583 ha (105,224 ac) are used for agriculture. Columbia, Orange, and Rensselaer counties comprise the set of counties with the second highest areas of agricultural lands in the Hudson Valley (33,879, 29,789, and 28,706 ha [83,718, 73,605, and 70,933 ac], respectively) (figure 3). The counties in closest proximity to New York City—Westchester, Putnam, and Rockland—have the least land area allocated to agriculture within the Hudson Valley (0.65%, 0.37%, and 0.06%, respectively). However, Dutchess and Orange counties have both large areas of developed land and the most pasture and cultivated cropland of the 10 counties (figure 1).

Best Management Practices and Hudson Valley's Carbon Sequestration Potential. Ten years of simulated management scenarios led to substantially different estimates for the total C sequestration. Under Improved practices (scenario #3), conservation/no-tillage and rotational grazing were predicted to sequester on average 3.51 Mg CO_2 ha^{-1} yr^{-1} (1.55 tn CO_2 ac^{-1} yr^{-1}) for all counties in the Hudson Valley (figure 4). Conversion of farmland to pasture under the CRP (scenario #2) also led to C sequestration (1.34 Mg CO_2 ha^{-1} yr^{-1} [0.59 tn CO_2 ac^{-1} yr^{-1}]) in all counties, but sequestration under scenario #2 was less than half of the sequestration potential of scenario #1 (figure 4). No-till management provides a viable alterna-

Figure 2

Estimated location and size of agricultural parcels (includes land managed for crops, orchards, vineyards, poultry farms, nurseries, and pasture) in the Hudson Valley, New York (2007). Data source: New York State Office of Real Property Services.



tive to conventional tillage but should not be adopted unless a farmer already has cropped fields. That is, converting from heavily grazed pasture to no-till crops leads to CO_2 emissions rather than sequestration. Of the three management scenarios, maintaining conventional farming practices was the only scenario to lose soil C rather than serve as a C sink (0.27 Mg CO_2 ha^{-1} yr^{-1} [0.12 tn CO_2 ac^{-1} yr^{-1}] emissions for all counties). Our estimates are similar to estimates from an analysis of C sequestration rates from a global database of long-term agricultural experiments for the conversion from conventional tillage to no-till (57±14 g C m^{-2} yr^{-1} or ~2.09 Mg C ha^{-1} yr^{-1} [0.92 tn C ac^{-1} yr^{-1}]) (West and Post 2002). Although on the same order of magnitude, the slightly lower estimates of C sequestration potential for the conversion of conventional tillage to no-tillage in our study (3.51 Mg CO_2 ha^{-1} yr^{-1} [1.55 tn CO_2 ac^{-1} yr^{-1}] or 0.96 Mg C ha^{-1} yr^{-1} [0.42 tn C ac^{-1} yr^{-1}]) compared to the estimates in West and Post (2002) may have arisen from the differences in the duration of the studies from which the estimates were taken, differences in soil types, and possibly because estimates from our study were simulated and those of West and Post (2002) were taken from field observations.

What is the Potential for Carbon Trading in the Hudson Valley? Based on our estimates of C sequestration potential for the best management practice scenario (3.51 Mg CO_2 ha^{-1} yr^{-1} [1.55 tn CO_2 ac^{-1} yr^{-1}]), it is apparent that improved management practices (e.g., conservation and no-tillage) translate into a relatively small C market for the Hudson Valley. At the time of this study (2008), the Chicago Climate Exchange, the C trading facilitator in the United States, assigned \$1.50 Mg^{-1} (\$1.65 tn^{-1}) CO_2-C (http://www.ccfe.com); therefore, the C market of the Hudson Valley would consist of ~\$1,117,000 distributed over 10 counties. The limited potential of C sequestration is expected to decrease as the soil reaches a new C equilibrium after the new management practice has been in place for 15+ years (Johnson et al. 1995). However, from another perspective, a single car in the United States emits approximately 5.23 Mg CO_2e per vehicle yr^{-1} (5.77 tn CO_2e per vehicle yr^{-1}) (USEPA 2009). If all farms in the Hudson Valley convert to sustainable management, the annual CO_2 emissions of 117,391 cars could potentially be offset. This emphasizes the importance of studying a wide range of C sequestration options, even relatively small ones, in order to provide a robust response to the challenges of climate change.

Accurate and reliable estimates of regional soil C sequestration potential are crucial to aiding policymakers and farmers who seek to create C credit programs. In the next stage of this study, we plan to obtain higher resolution soil and land use data to incorporate into more detailed ecosystem models (e.g., DayCENT [a daily time-step version of CENTURY] and DNDC [DeNitrification-DeComposition]) in order to project greenhouse gas emissions, such as nitrous oxide (N_2O) and methane (CH_4) emissions along with CO_2 emissions, associated with different agricultural management in the Hudson Valley. Ultimately, we aim to develop a framework for identifying management practices that reduce GHG emissions and promote sustained climate change mitigation and adaptation strategies on similar small-scale agricultural regions.

SUMMARY AND CONCLUSIONS

Calculating the soil C sequestration potential of Hudson Valley farms is an important initial step in the effort to develop best

Figure 3

Total agricultural land area in the 10 counties of the Hudson Valley, New York (176,042 ha [435,009 ac]).

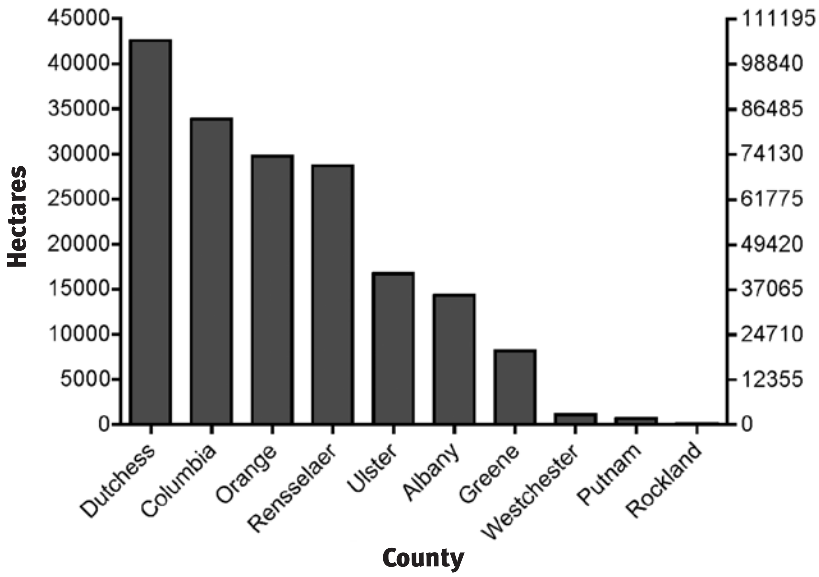
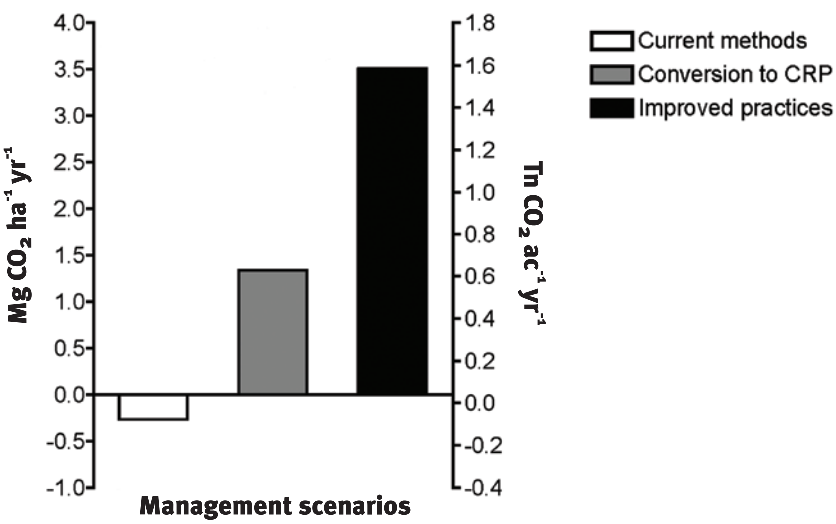


Figure 4

Estimates of CO_2 sequestration based on a 10-year projection from COMET-VR for three management scenarios in the agricultural lands in the Hudson Valley, New York: Current methods, conversion to Conservation Reserve Program (CRP), and Improved practices. Ninety-five percent confidence intervals were not determined.



management practices and to reduce GHG emissions for the region. Although our estimates of C sequestration potential for the Hudson Valley translate into a relatively small C market (approximately 3.51 Mg CO_2 ha^{-1} yr^{-1} [1.55 tn CO_2 ac^{-1} yr^{-1}] sequestered), the knowledge that conservation tillage and rotational grazing management can make a difference for soil C sequestration compared to conventional farming practices is vital information for policy makers and farmers alike. Moreover, this study is among the first to demonstrate the potential for obtaining reliable estimates of soil C sequestration on a region characterized by small-scale and diverse farming.

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